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Effect of Sowing Methods on the Performance of Soybean (*Glycine max* L.) Varieties

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ABSTRACT

Soybean is one of the most commercially significant beans grown globally. The productivity of soybean cultivation in India varies considerably based on factors such as soil composition, climatic conditions, variety and agricultural practices including sowing methods. A field experiment was conducted at Agronomy Research Farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema campus, entitled "Effect of sowing methods on the performance of soybean (*Glycine max* L.) varieties" during the *kharif* season 2023. The treatments consisted of two sowing methods viz., line sowing and broadcasting and four varieties of soybean viz., RKS-113, MACS-1460, JS 20-116 and JS 97-52 (check variety). The results revealed that line sowing recorded the highest growth and yield attributes, excluding plant population, root dry matter accumulation at 50 DAS, number of nodules plant^{-1} at 50 DAS, number of seeds pod^{-1} and test weight. Among the four soybean varieties, JS 20-116 recorded the highest plant population, plant height, dry matter accumulation, leaf area index, crop growth rate, relative growth rate, root length, root dry matter accumulation, nodules plant^{-1}, fresh weight of nodules, dry weight of nodules, number of pods plant^{-1}, number of filled pods plant^{-1}, pod weight plant^{-1} , seed weight plant^{-1}, length of pod, number of seeds pod^{-1}, test weight, seed yield, stover yield, biological yield and harvest index. However, shelling (%) was found to be higher in JS 97-52. The maximum seed yield and stover yield after JS 20-116 was found to be in RKS-113. Among all the varieties studied, treatment combination of M_1V_3 i.e., line sowing + JS 20-116 variety recorded the maximum net return and maximum benefit cost ratio over all the treatment combination.

Keywords Soybean, Sowing methods, Growth attributes, Yield attributes, Varieties, Economics.

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INTRODUCTION

Soybean (*Glycine max*), also known as soya bean or soja bean, is an annual legume from the pea family

called Fabaceae. It supplies vegetable protein to a large number of people worldwide and is also used as a constituent in several chemical goods. Soybean stands out as one of the most abundant and cost-effective sources of protein globally, serving as a dietary staple for both humans and animals across various regions. With its seeds comprising 17% oil and 63% meal, half of which is protein, soybeans offer a substantial nutritional value. It has swiftly risen to prominence as India's leading oilseed crop, boasting approximately 10 million hectares dedicated to its cultivation within a relatively short span. Meanwhile, in Nagaland, the Department of Agriculture reported that soybean cultivation covered an area of 4,400 hectares in the 2020-2021 period, resulting in a total production of 5,280 metric tonnes, with a productivity rate of 1.2 metric tonnes per hectare. Enhancing soybean production hinges significantly on the adoption of improved cultural practices and effective management techniques. Among these practices, selecting the appropriate sowing method and optimizing seed rates are paramount. While the traditional broadcasting method remains suitable for fodder and green manure crops, it presents challenges such as uneven plant distribution, complicating tasks like weeding and hoeing. Alternatively, employing a row sowing technique, facilitated by see drills or ploughs, offers better control over plant spacing and ensures optimal plant density for maximizing yields. Given the intense competition among plants for vital resources like nutrients, sunlight, moisture and air, it is crucial to determine the most effective pairing of sowing techniques, seed quantities and the variety of seeds to attain the highest soybean yield possible.

MATERIALS AND METHODS

A field experiment was carried out in the experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema, Campus during the *kharif* season of 2023, situated at an attitude of 310 meters above the mean sea level with the geographical location of 25˚C 45'43" North latitude and 95˚53'04" East longitude. The experiment followed a Factorial Randomized Block Design with three replications. The entire experimental field was divided into three equal blocks, each further subdivided into eight sub-plots measuring 4.5 m × 3 m. Treatments were randomly assigned to the sub-plots within each block. Two methods of sowing were studied in the experiment, namely Line sowing (M_1) and Broadcasting (M_2) and four varieties were used for the experiment which is RKS-113 (V_1), MACS-1460 (V_2), JS 20-116 (V_3) and JS 97-52 (V_4). The experimental plot was ploughed using a tractor-drawn plough, followed by the utilization of a rotavator to break up clods and eliminate the hardpan. Soil samples were gathered from various locations using a soil auger, selected at random. These samples underwent mechanical and chemical analysis for processing. The soil condition of the experiment farm was found to be well drained and sandy loam in texture. At the time of sowing, the recommended fertilizer dose of 25 kg of urea, 100 kg of single super phosphate, and 50 kg of muriate of potash per hectare were broadcasted in the field as basal dose. After soaking the seeds in the Vitavax solution at the rate of 3g kg^{-1} seeds for 30 minutes, it was dried in shade and then sown. Seeds at the rate of 80 kg^{-1} were used for sowing. The seeds required for each treatment was calculated and were sown in 45 cm × 10 cm inter and intra row spacing by opening furrows at the assigned plots where line sowing was to be followed and at the broadcasted plots, the seeds were spread randomly by hand. 2-3 seeds were manually dibbled at a depth ranging from 3 to 5 cm. To determine the various growth and yield characteristics of the plants, five plants excluding the border plants were selected at random from each plot and then they were tagged. The readings of the growth characteristics were recorded at different stages of the crop growth (25, 50 and 75 DAS). From the five tagged plants, the number of pods $plant^{-1}$ and number of filled pods $plant^{-1}$ were counted manually from each treatment and average was worked out. The pod and seed weight were taken from the separated pods in each treatment and then their average was calculated to obtain the pod and seed weight $plant^{-1}$. The shelling percentage was computed by dividing the seed weight over weight of pods and then multiplied by 100. The number of seeds per pod was obtained by determining the number of seeds obtained from the ten separated pods in each treatment and then computing the mean. For test weight, one thousand seeds were randomly sampled and counted from the seed yield of each plot within the net area. The yield obtained from the net area of each plot was recorded as grain yield, and then

it was converted into kg ha^{-1}. Stover yield per net area was calculated by subtracting the grain yield from the total yield of the net plot area. The biological yield was calculated by adding the values obtained from the seed yield and stover yield. Harvest index was calculated by dividing economic yield by biological yield and multiplied by 100. The economics was calculated using prevailing prices of inputs and outputs. The data recorded for each character were subjected to statistical analysis using analysis of variance (F-test) following the methodology proposed by Gomez and Gomez (1976). When statistical significance was detected, a crucial difference (CD) was calculated at a significance level of 0.05 for comparison.

RESULTS AND DISCUSSION

The data collected and recorded from the experiment on various aspects have been statistically analyzed and the result obtained from various parameters are presented in Tables 1– 4.

Effect of sowing methods

The sowing method affected the growth and yield attributes. The growth contributing parameters viz., plant height (33.59, 46.39, 63.10 cm) at 25, 50 and 75 DAS respectively, dry matter accumulation (16.82) at 75 DAS, LAI (0.40, 1.26, 2.59) at 25,50 and 75 DAS, CGR (8.38) at 25-50 DAS, RGR (0.040, 0.070) at 25-50 and 50-75 DAS presented in Table 1, root length (19.48, 23.49) at 50 and 75 DAS, root dry matter accumulation (0.49, 1.71) at 25 and 75 DAS, number of nodules plant^{-1} (19.52, 53.59) at 25 and 75 DAS, fresh weight of nodules (288.46, 697.39, 1031.66) at 25, 50 and 75 DAS, dry weight of nodules (181.17,

Table 1. Effect of sowing method, varieties and its interaction effect on the growth parameters of soybean.

Treatment	Plant population (m^{-2})			Plant height (cm)			Dry matter accumulation (g plant^{-1})		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
Method of sowing									
M_1 – Line sowing	21.13	20.42	20.32	33.59	46.39	63.10	1.23	10.66	16.82
M_2 - Broadcasting	21.00	20.27	20.10	32.12	45.41	61.71	1.20	9.01	14.75
SEm ±	0.20	0.20	0.16	0.37	0.26	0.38	0.01	0.17	0.19
CD (p=0.05)	NS	NS	NS	1.14	0.79	1.16	0.03	0.53	0.59
Varieties									
V_1– RKS- 113	21.25	20.42	20.25	33.58	46.37	62.79	1.22	10.07	15.52
V_2 – MACS-1460	20.17	19.87	19.82	30.77	45.22	61.65	1.17	8.26	13.85
V_3 – JS 20-116	21.67	21.08	20.83	34.97	46.83	63.81	1.25	11.95	18.50
V_4 – JS 97-52	21.17	20.00	19.92	32.11	45.19	61.38	1.21	9.06	15.26
SEm ±	0.29	0.28	0.22	0.53	0.37	0.54	0.01	0.25	0.27
CD (p=0.05)	0.88	0.86	0.68	1.62	1.12	1.65	0.04	0.76	0.84
Interaction effect of sowing methods and varieties on growth parameters of soybean									
M_1V_1	21.50	20.30	20.30	35.30	46.80	63.10	1.23	11.44	16.51
M_1V_2	20.30	19.80	19.80	30.90	46.10	63.00	1.20	8.79	14.74
M_1V_3	21.70	21.20	21.00	35.30	47.10	64.80	1.25	13.15	20.31
M_1V_4	21.00	20.30	20.20	32.90	45.60	61.60	1.21	9.24	15.70
M_2V_1	21.00	20.50	20.20	31.90	45.90	62.50	1.20	8.69	14.53
M_2V_2	20.00	19.90	19.90	30.60	44.40	60.30	1.13	7.72	12.95
M_2V_3	21.70	21.00	20.70	34.97	46.50	62.80	1.25	10.74	16.68
M_2V_4	21.30	19.70	19.70	32.11	44.80	61.20	1.19	8.87	14.81
SEm ±	0.41	0.40	0.32	0.75	0.52	0.77	0.02	0.35	0.39
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	1.07	1.18

Table 1. Continued.

Treatment	Leaf area index			Crop growth rate (g m^{-2} day^{-1})		Relative growth rate (g $g^{-1}$$day^{-1}$)	
	25 DAS	50 DAS	75 DAS	25-50 DAS	50-75 DAS	25-50 DAS	50-75 DAS
				Method of sowing			
M_1 – Line sowing	0.40	1.26	2.59	8.38	5.48	0.040	0.070
M_2 - Broadcasting	0.36	1.23	2.39	6.94	5.10	0.034	0.070
SEm ±	0.009	0.006	0.048	0.15	0.09	0.0003	0.0003
CD (p=0.05)	0.030	0.020	0.147	0.47	0.28	0.0010	0.0010
				Varieties			
V_1– RKS-113	0.38	1.26	2.54	7.86	4.85	0.040	0.070
V_2 – MACS-1460	0.33	1.16	2.21	6.30	4.97	0.030	0.070
V_3 – JS 20-116	0.44	1.32	2.79	9.51	5.82	0.040	0.070
V_4 – JS 97-52	0.36	1.24	2.43	6.98	5.52	0.030	0.070
SEm ±	0.014	0.009	0.068	0.22	0.13	0.0005	0.0004
CD (p=0.05)	0.042	0.028	0.208	0.67	0.40	0.0010	0.0010
				Interaction effect of sowing methods and varieties on growth parameters of soybean			
M_1V_1	0.40	1.30	2.60	9.06	4.50	0.038	0.069
M_1V_2	0.30	1.20	2.30	6.74	5.29	0.034	0.069
M_1V_3	0.50	1.30	2.90	10.57	6.36	0.040	0.075
M_1V_4	0.40	1.30	2.50	7.13	5.74	0.035	0.071
M_2V_1	0.40	1.20	2.40	6.65	5.18	0.034	0.069
M_2V_2	0.30	1.20	2.20	5.85	4.64	0.033	0.066
M_2V_3	0.40	1.30	2.60	8.43	5.28	0.037	0.071
M_2V_4	0.40	1.20	2.30	6.82	5.28	0.034	0.069
SEm±	0.019	0.013	0.096	0.31	0.18	0.0007	0.0006
CD (p=0.05)	0.060	0.039	NS	0.94	0.56	0.0020	0.0020

409.60, 491.31) at 25, 50 and 75 DAS presented in Table 2 as well as yield contributing parameters viz., number of pods $plant^{-1}$ (47.91), number of filled pods $plant^{-1}$ (42.71), pod weight $plant^{-1}$ (9.61), seed

Table 2. Effect of sowing method, varieties and its interaction effect on the root studies of soybean.

Treatment	Root length (cm)		Root dry matter accumulation (g $plant^{-1}$)			No. of nodules $plant^{-1}$		
	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
				Method of sowing				
M_1-Line sowing	19.48	23.49	0.49	0.86	1.71	19.52	33.92	53.59
M_2 - Broadcasting	18.45	22.21	0.43	0.83	1.67	19.08	33.76	51.96
SEm ±	0.16	0.13	0.010	0.012	0.007	0.12	0.16	0.13
CD (p=0.05)	0.48	0.42	0.032	NS	0.024	0.37	NS	0.42
				Varieties				
V_1– RKS-113	19.16	23.31	0.47	0.87	1.70	19.52	34.52	52.62
V_2 – MACS-1460	17.02	20.57	0.37	0.77	1.61	18.41	32.52	51.60
V_3 – JS 20-116	21.23	24.84	0.58	0.94	1.76	20.08	34.74	54.61
V_4 – JS 97-52	18.45	22.68	0.42	0.81	1.69	19.18	33.59	52.28
SEm ±	0.22	0.19	0.015	0.017	0.011	0.17	0.23	0.19
CD (p=0.05)	0.68	0.59	0.045	0.052	0.034	0.52	0.72	0.59

Table 2. Continued.

Treatment	Root length (cm)		Root dry matter accumulation (g plant^{-1})			No. of nodules plant^{-1}		
	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
Interaction effect of sowing methods and varieties on root studies of soybean								
M_1V_1	19.40	24.10	0.50	0.90	1.70	19.70	34.50	53.20
M_1V_2	18.10	21.20	0.40	0.80	1.60	18.40	32.50	52.50
M_1V_3	21.90	25.90	0.60	1.00	1.80	20.60	34.90	55.70
M_1V_4	18.60	22.80	0.40	0.80	1.70	19.30	33.90	53.10
M_2V_1	19.00	22.60	0.50	0.90	1.70	19.30	34.50	52.10
M_2V_2	16.00	19.90	0.40	0.70	1.60	18.40	32.60	50.70
M_2V_3	20.50	23.80	0.50	0.90	1.70	19.50	34.60	53.50
M_2V_4	18.30	22.60	0.40	0.80	1.7	19.10	33.30	51.50
SEm ±	0.32	0.27	0.021	0.024	0.015	0.24	0.33	0.27
CD (p=0.05)	0.97	0.84	NS	NS	NS	NS	NS	NS

Table 2. Continued.

Treatment	Fresh weight of nodules (mg plant^{-1})			Dry weight of nodules (mg plant^{-1})		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
Method of Sowing						
M_1 – Line sowing	288.46	697.39	1031.66	181.17	409.60	491.31
M_2 - Broadcasting	285.71	640.19	978.54	169.03	386.37	469.94
SEm ±	0.10	0.35	0.29	0.19	1.17	1.56
CD (p=0.05)	0.33	1.08	0.90	0.59	3.56	4.73
Varieties						
V_1– RKS-113	286.85	731.55	1134.14	170.32	408.83	499.76
V_2 – MACS-1460	283.85	528.50	721.79	156.05	335.60	447.90
V_3 – JS 20-116	292.02	781.87	1208.38	210.20	455.58	511.44
V_4 – JS 97-52	285.63	633.24	956.09	163.83	391.93	463.40
SEm ±	0.15	0.50	0.42	0.27	1.66	2.20
CD (p=0.05)	0.46	1.53	1.28	0.84	5.03	6.69
Interaction effect of sowing methods and varieties on root studies of soybean						
M_1V_1	288.30	762.70	1168.20	173.10	421.90	503.60
M_1V_2	285.50	553.80	742.30	160.80	340.90	464.80
M_1V_3	293.50	810.00	1229.00	222.90	465.10	520.10
M_1V_4	286.50	663.00	987.20	167.90	410.50	476.70
M_2V_1	285.30	700.40	1100.10	167.50	395.70	495.90
M_2V_2	282.20	503.20	701.30	151.30	330.30	431.00
M_2V_3	290.50	753.80	1187.80	197.50	446.00	502.80
M_2V_4	284.80	603.40	925.00	159.80	373.40	450.10
SEm ±	0.21	0.71	0.59	0.39	2.34	3.12
CD (p=0.05)	0.66	2.17	1.81	1.19	7.12	9.46

weight plant^{-1} (7.45), shelling (%) (69.87), length of pod (4.22), grain yield (1304.64 kg ha^{-1}), stover yield (2122.55 kg ha^{-1}), biological yield (3427.18 kg ha^{-1}) presented in Table 3 were significantly higher in line sowing over broadcasting. The higher number of unfilled pods in broadcasted plots may have been due to higher competition for space, light, water, in densely populated plants. Similar line of work was also reported by Hamid *et al*. (2002) where the number of filled pods plant^{-1} was higher in line sowing

Table 3. Effect of sowing method, varieties and its interaction effect on the yield and yield attributes of soybean.

Treatment	Number of pods plant^{-1}	Number of filled pods plant^{-1}	Pod weight plant^{-1}	Seed weight plant^{-1}	Shelling (%)	Length of pod
			Method of sowing			
M_1 – Line sowing	47.91	42.71	9.61	7.45	69.87	4.22
M_2 - Broadcasting	35.73	30.80	9.41	6.86	65.26	3.24
SEm ±	0.30	0.19	0.05	0.01	0.13	0.08
CD (p=0.05)	0.91	0.60	0.17	0.05	0.41	0.26
			Varieties			
V_1– RKS-113	43.92	37.16	9.67	7.37	62.98	3.97
V_2– MACS-1460	36.50	31.73	8.91	5.84	62.83	3.07
V_3 –JS 20-116	46.30	42.42	10.07	8.23	66.90	4.78
V_4– JS 97-52	40.58	35.71	9.40	7.19	77.55	3.11
SEm ±	0.42	0.28	0.08	0.02	0.19	0.12
CD (p=0.05)	1.29	0.85	0.25	0.07	0.58	0.37
	Interaction effect of sowing methods and varieties on yield and yield attributes of soybean					
M_1V_1	50.90	44.00	9.70	7.90	66.20	4.40
M_1V_2	41.50	36.60	9.00	5.80	66.00	3.30
M_1V_3	51.80	47.80	10.30	8.50	69.10	5.70
M_1V_4	47.50	42.40	9.50	7.50	78.30	3.50
M_2V_1	37.00	30.30	9.60	6.90	59.80	3.50
M_2V_2	31.50	26.80	8.90	5.80	59.70	2.80
M_2V_3	40.80	37.10	9.80	7.90	64.70	3.90
M_2V_4	33.70	29.00	9.30	6.80	76.80	2.70
SEm ±	0.60	0.39	0.11	0.03	0.27	0.17
CD (p=0.05)	1.83	1.21	NS	0.10	0.83	0.52

Table 3. Continued.

Treatment	Number of seeds pod^{-1}	Test weight	Seed yield	Stover yield	Biological yield	Harvest index (%)
			Method of sowing			
M_1 – Line sowing	2.50	109.38	1304.64	2122.55	3427.18	37.81
M_2 – Broadcasting	2.58	109.34	1112.22	1771.12	2883.34	38.45
SEm ±	0.02	0.13	15.41	23.19	36.69	0.20
CD (p=0.05)	0.06	NS	46.76	70.34	111.12	0.61
			Varieties			
V_1– RKS-113	2.61	112.55	1306.01	2010.06	3316.07	39.35
V_2– MACS-1460	2.37	98.64	874.81	1546.89	2421.70	36.26
V_3 –JS 20-116	2.78	114.45	1507.73	2307.60	3815.33	39.51
V_4– JS 97-52	2.41	111.81	1145.17	1922.78	3067.95	37.39
SEm ±	0.02	0.18	21.80	32.79	51.80	0.28
CD (p=0.05)	0.08	0.56	66.13	99.48	157.14	0.87
	Interaction effect of sowing methods and varieties on yield and yield attributes of soybean					
M_1V_1	2.60	112.30	1479.31	2257.67	3736.98	39.59
M_1V_2	2.30	99.00	944.11	1741.82	2685.93	35.14
M_1V_3	2.80	114.40	1541.77	2332.18	3873.95	39.80
M_1V_4	2.30	111.80	1253.34	2158.52	3411.86	36.73
M_2V_1	2.60	112.80	1132.70	1762.46	2895.16	39.12
M_2V_2	2.40	98.30	805.51	1351.96	2157.48	37.39
M_2V_3	2.80	114.50	1473.68	2283.02	3756.71	39.22
M_2V_4	2.50	111.90	1036.99	1687.05	2724.04	38.06
SEm ±	0.04	0.26	30.83	46.38	73.27	0.40
CD (p=0.05)	NS	NS	93.52	140.68	222.24	1.23

Table 4. Effect of sowing methods on cost of cultivation, gross returns, net returns and B:C ratio.

Treatment	Cost of cultivation	Gross returns	Gross returns	B:C ratio
M_1V_1	39797	70306.16	30509.16	1.76
M_1V_2	39797	45170.95	5373.95	1.13
M_1V_3	39797	73253.83	33456.83	1.84
M_1V_4	39797	59812.42	20015.42	1.50
M_2V_1	37797	53866.52	16069.52	1.42
M_2V_2	37797	38405.58	608.58	1.01
M_2V_3	37797	63189.20	25392.2	1.67
M_2V_4	37797	49388.61	11591.61	1.30

than broadcasting method. Higher seed weight plant^{-1} could be due to adequate space provided to fulfill the plant requirements for development. Similar line of work is reported by Fadeev *et al.* (2021) where it can be seen that with ordinary sowing, lower yields are achieved in comparison with wide-row sowing. Improper depth could have inhibited germination of seed in broadcasting accompanied by competition for space, light and water. Similar line of work was reported by Chaurasiya (2013), Hamid *et al.* (2002), Wakweya and Meleta (2016), Ram *et al.* (2018), and Pokhrel *et al.* (2022) where it was observed that line sowing produced more yield as compared to broadcasting.

Effect of varieties

The growth contributing parameters viz., plant population (21.67), dry matter accumulation (1.25, 11.95, 18.50) at 25, 50 and 75 DAS, LAI (0.44, 1.32, 2.79) at 25, 50 and 75 DAS, CGR (9.51, 5.82) at 25-50 DAS and 50-75 DAS, RGR (0.040, 0.070) at 25-50 DAS and 50-75 DAS revealed in Table 1, root length (21.23, 24.84) at 50 and 75 DAS, root dry matter accumulation (0.58, 0.94, 1.76) at all 25, 50 and 75 DAS, number of nodules plant^{-1} (20.08, 34.74, 54.61) at 25, 50 and 75 DAS, fresh weight of nodules (292.02, 781.87, 1208.38) at 25, 50 and 75 DAS, dry weight of nodules (210.20, 455.58 and 511.44) at 25, 50 and 75 DAS revealed in Table 2 as well as yield contributing parameters viz., number of pods plant^{-1} (46.30), number of filled pods plant^{-1} (42.42), pod weight plant^{-1} (10.07), seed weight plant^{-1} (8.23), shelling (%) (66.90), length of pod (4.78), number of seed pod^{-1} (2.78), test weight (114.45), seed yield (1507.73 kg ha^{-1}), stover yield (2307.60 kg ha^{-1}), biological yield (3815.33 kg ha^{-1}), harvest index (39.5 %) revealed in Table 3 were significantly higher in V_3 (JS 20–116) over the other varieties. At 25 DAS, the highest plant height was observed in V_3 (JS 20-116) (34.97 cm) which was at par with V_1 (RKS-113) (33.58 cm), at 50 DAS, the highest was observed in V_3 (JS 20-116) (46.83 cm) which was at par with V_1 (RKS-113) (46.37 cm), and at 75 DAS, the highest was also observed in V_3 (63.81 cm) which was at par with V_1 (RKS-113) (62.79 cm). The results obtained from the experiment are in close conformity with the findings of Reni and Rao (2013) where forty five genotypes of soybean (*Glycine max* (L.) Merrill.) of diverse origin were evaluated for variability, heritability and genetic advance. High heritability coupled with high genetic advance as percent of mean was observed for growth and yield parameters such as plant height, pods plant^{-1}, pod length, seeds pod^{-1}.

Interaction effect

The interaction effect of sowing methods and varieties had significant effect on the growth and yield parameters. In Table 1, treatment M_1V_3 (Line sowing + JS 20-116) recorded the highest dry matter accumulation (13.15, 20.31) at 50 and 75 DAS, LAI (0.50) at 25 and (1.30) at 50 DAS which was at par with M_1V_1, M_1V_4 and M_2V_3, CGR (10.57, 6.36) at 25–50 DAS and 50–75 DAS, RGR (0.040) at 25–50 DAS which was at par with M_1V_1 (0.038) and (0.075) at 50-75 DAS, in Table 2, root length (21.90, 25.90) at 50 DAS and 75 DAS, fresh weight of nodules (293.50, 810.00, 1229.00) at 25,50 and 75 DAS, dry weight of nodules (222.90, 465.10 and 520.10) at 25,50 and 75 DAS also in Table 3, number of pods plant^{-1} (51.80) which was at par with treatment M_1V_1 (50.90), number of filled pods plant^{-1} (47.80), seed weight plant^{-1} (8.50), shelling (%) (69.10), length of pod (5.70), seed yield (1541.77 kg ha^{-1}), stover yield (2332.18 kg ha^{-1}), biological yield (3873.95 kg ha^{-1}), harvest index (39.80 %) which was at par with M_1V_1 (39.59%), M_2V_1 (39.12%), M_2V_3 (39.22%).

Economics

The data in Table 4 revealed that the treatment combinations M_1V_1, M_1V_2, M_1V_3, M_1V_4 was observed to

yield the highest cost of cultivation. This was due to more number of laborers required for operations such as sowing and intercultural operation like weeding, gap filling and thinning. The maximum gross return (₹ 73253.8 ha^{-1}) and net return (₹ 33456.8 ha^{-1}) was recorded in M_1V_3 i.e. line sowing + JS 20-116 variety. Similarly, the maximum benefit cost ratio (1.8) was also recorded in M_1V_3 i.e. line sowing + JS 20-116 variety. Likewise, Chaurasiya (2013) also reported that the raised bed method of sowing provided the maximum net return to the tune of ₹ 33957 ha^{-1} with 1.68 B:C ratio. Singh *et al.* (2016) concluded that the improved variety yielded higher gross returns (₹ 40,000 – 78,900) and net returns (₹ 24,500 – 60,300) compared to the local cultivar (₹ 30,000 –52,800) and (₹ 16,000 – 35,300) respectively.

CONCLUSION

It can be inferred that among the methods of sowing, M_1 i.e., line sowing resulted in producing higher seed yield as compared to broadcasting. Among all the varieties, JS 20-116 was found to be the best performing variety in terms of growth parameters, root studies, yield and yield attributes. The best suited variety soybean observed from the experiment was found to be JS 20-116. The treatment combination M_1V_3 i.e., line sowing + JS 20-116 was recorded to obtain highest economic gain with net return of ₹ 33456.83 and Benefit cost ratio of 1.84.

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